NASA TECHNICAL MEMORANDUM NASA TM-76793

DETERMINATION OF OXYGEN TENSION IN THE SUBCUTANEOUS TISSUE OF COSMONAUTS DURING THE SALYUT-6 MISSION

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N82-20864
Unclas
09404

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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STANDARD TITLE PAGE

1. Report No. NASA TM-76793	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle DETERMINATION OF OXYGEN TENSION IN THE SUBCUTANEOUS TISSUE OF COSMONAUTS DURING THE SALYUT-6 MISSION		5. Report Date MARCH 1982
		6. Performing Organization Code
7. Author(s) S. Baranski, R. Bloszczynski, M. Hermaszewski, J. Kubiczkowa, A. Piorko, R. Saganiak, Z. Sarol, F. Skibniewsky, J. Stendera, and W. Walichnowski		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California 94063		11. Contract or Grant No. NASw- 3541
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes Translation of "Oznaczenie cisnienia czastkowego tlenu w tkance podskornej kosmonautow podczas lotu w stacji kosmicznej 'Salut-6'," Postepy astronautyki, Vol. 12, No. 4, 1979, pp. 75-80.

(See A80-30518) 52

16. Abstract

A polarographic technique was used to measure the oxygen tension in subcutaneous tissue of the forearm of cosmonaut Hermaszewski prior to, after, and on the fourth day of a space mission performed by Salut-6. A drop in the oxygen exchange rate in the peripheral tissues during weightlessness was observed. The mechanisms of this change are studied, taking into consideration the blood distribution in the organism and microcirculation disorders reflected by a decreased blood flow rate in arterial-venous junctions.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified	Unclassified	6	

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OF POOR QUALITY

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The problems of gas exchange in a cosmonaut's organism under space flight conditions are of fundamental importance. Many factors connected with space flight may have an influence on the oxygenation of the blood, the intensity of oxygen transport, as well as on its consumption in the organism's tissues. /75*

The artificial atmosphere in a vessel or orbital station may deviate from a fixed norm, bringing about changes in blood oxygen saturation. Accelerations occurring in the course of active flight, weightlessness occurring in orbital flight occasioning changes in the flow and distribution of blood in the organism, an increase in blood in the so-called central portion of the circulation, changes in pulmonary circulation or in the capillaries, may disrupt the processes of an organism's gas exchange. Changes in the metabolism during weightlessness brought about by changes in muscle system loading should also be taken into account. It is from this, then, that studies on the molecular oxygen tension in the tissues under space flight conditions have fundamental significance, both theoretical as well as practical, broadening our ability to evaluate the state of an active organism, as well as being able to describe the effectiveness of means for maintaining life in outer space.

The method of polarography has found a place in the study of oxy- /76
gen tension in the tissues, pO_2. As a result of scientific cooperation between specialists in the Soviet Union and Czechoslovakia,

*Numbers in the margin indicate pagination in the foreign text.

equipment for these kinds of studies, an oksymeter, was developed and placed onboard the Salut-6 orbital station. The first version of these studies was carried out during the combined Sojuz-29 - Salut-6 orbital flight involving the Czech cosmonaut, V. Remek.

These studies were continued by the first Polish cosmonaut, M. Hermaszewski. Measurements of the pO_2 were taken in the subcutaneous tissue of the forearm using an implanted platinum electrode (Fig. 1).

The first series of studies on the cosmonaut were carried out at the fourteenth and twelfth days before lift-off; these became the base norm and were compared with the results of studies carried out on a control group as well.

During atmospheric air respiration, the oxygen tension in the subcutaneous tissue of M. Hermaszewski was 56.7 and 47.6 mm Hg (in the first as well as the second test). These amounts were higher in comparison with the control group (37±0.9 mm Hg).

During the hyperventilation test, the pO_2 increased to 62.2±55.5 mm Hg (in both the first and second tests). The hypocapnia caused by the extended period of hyperventilation caused in its turn a drop in the pO_2 in the tissues to values of 51.2 and 43.9 mm Hg, that is, drops of 5.5 and 3.7 mm Hg.

In a subsequent test, the pO_2 in the subcutaneous tissue for the respiration of pure oxygen increased to 140.9 and 139.0 mm Hg (the first and second tests). M. Hermaszewski's reaction to hyperoxia was less pronounced than in comparison with the control group (174±8.1 mm Hg). M. Hermaszewski's oxygen consumption rate in the initial base tests was relatively greater, amounting to 18.9 and 15.9 mm Hg/min. These amounts were greater in comparison with the amounts derived from the control group (12.8±0.3 mm Hg/min).

During respiration of a mixed gas with oxygen fractions (pO_2=
=204 mm Hg) characteristic for the Salut-6 orbital station cabin, the oxygen tension in the subcutaneous tissue was 59.6 mm Hg.

M. Hermaszewski carried out another series of tests in the Salut-6 craft at the fourth day into flight. The oxygen tension in the subcutaneous tissue was 49.5 mm Hg, that is, 9.9 mm Hg lower than in the test results from Earth before the flight. A repeated measure taken /77

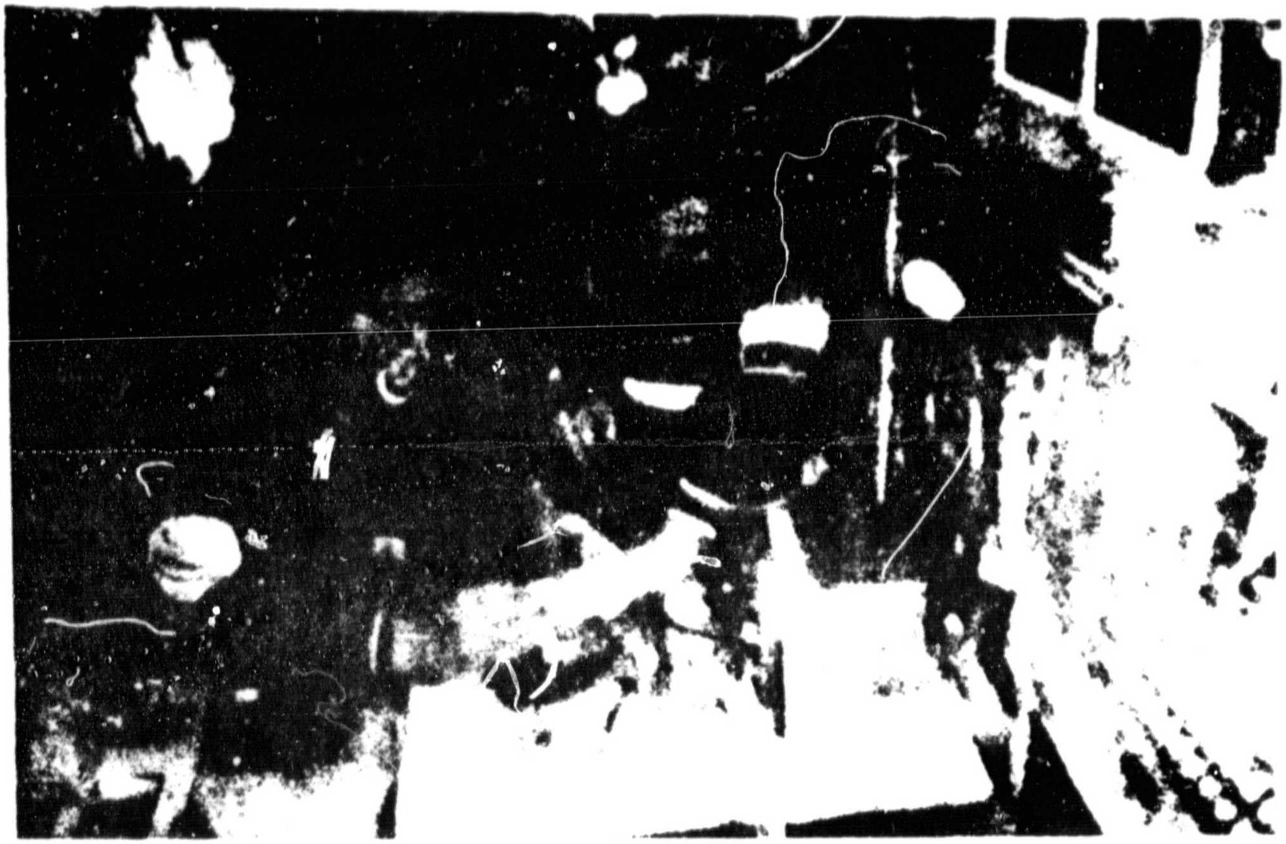

Fig. 1. Tests for oxygen tension in the subcutaneous tissue of cosmonaut M. Hermaszewski's arm during space flight. Cosmonaut P. Klimuk assisting in the procedure.

after the passage of several hours revealed an increase in the pO_2 in the tissues to a value of 53.4 mm Hg, and thereafter it was no less than 6.2 mm Hg lower than the norm on Earth.

M. Hermaszewski's oxygen consumption significantly lowered, amounting to 9.9 mm Hg/min. For comparison, in the test series before the flight, it was 18.9 and 15.9 mm Hg/min.

Another measure taken during the flight showed an increase in oxygen consumption to 17.8 mm Hg/min, closer to the initial base norm. Comparing these data with the results from the control group, we see that M. Hermaszewski's oxygen consumption in the first measurement was lower, whereas in the second it exceeded the average values generated from the test group. The variation in these reactions may be connected with the cosmonaut's level of activity, for example preceding level of active movement, emotional state, etc.

M. Hermaszewski carried out a test series at the third day after /78 the termination of the flight and return to Earth gravitation. The oxygen tension in the subcutaneous tissue for respiration of atmospheric air was 46.2 mm Hg, somewhat lower than the value before the flight (56.7 and 47.6 mm Hg). It was also somewhat lower in comparison with the average tension values in the control group (49±2 mm Hg).

An increase in the pO_2 of 3.3 mm Hg was noted for hyperventilation. The reaction to the oxygenation of blood and tissue was nevertheless somewhat less pronounced than before the flight (5.5 and 7.9 mm Hg), as well as in comparison with the control group reactions (an increase in pO_2 of 9.5 mm Hg).

During extended hyperventilation, accompanied by hypercapnia, there was a drop in oxygen tension in the subcutaneous tissue by 2.2 mm Hg (pO_2 = 44.0 mm Hg). The reaction to hypocapnia was less pronounced than before the flight, when drops in the pO_2 of 5.5 and 3.7 mm Hg in the first and second measurements were noted. Although the changes in pO_2 occurring as a result of hyperventilation were greater, still they were less pronounced than in the control group (a drop in pO_2 = 9.5 mm Hg). M. Hermaszewski's reaction to hyperventilation was, thus, less pronounced on the third day after return to Earth conditions.

Similar variations in P. Klimuka's reactions were determined.

A much greater increase in pO_2 in the subcutaneous tissue (154 mm Hg) than before the flight (140.9 and 130.0 mm Hg) was caused by the respiration of oxygen on the third day after termination of the flight. It did not, however, reach the values derived in the control group (174±8.1 mm Hg). Oxygen consumption determined in the tests carried out on the third day of readaptation to Earth gravity was 50.4 mm Hg/min, that is, it was close to the values derived in the second measurement carried out before the flight.

M. Hermaszewski's oxygen tension was somewhat lower after the flight in comparison with his initial base norm. At the same time, his reactions to pure oxygen respiration were much more pronounced.

The tests carried out during the orbital flight under conditions of weightlessness showed decreased rates of oxygen exchange in the peripheral tissues. These same kinds of changes were shown by P. Klimuk, as well as by crew mem[illegible] of the Soyuz-29 vessel, A. Gubariew /79
and V. Remek.

The main reason for a drop in oxygen tension in peripheral tissue may be changes in blood distribution in the organism displayed during weightlessness. The shift of blood to the upper part of the body is accompanied by symptoms of venous stagnation with disorders in the microcirculation, expressed by decreased blood flow at the arterio-venous junctions.

An oxygen tension determination in the subcutaneous tissue, carried out by Z. Kowalenkow, under conditions of long-term hypokinesis, as well as with changes in body position on an orthostatic table (angular deflections -15° and -30°), also showed a drop in pO_2, accompanied by changes in blood distribution as determined by a rheographic method. These studies demonstrated that the movement of blood to the upper part of the body, even over a short period of time, induces a drop in pO_2 in peripheral tissues.

Under conditions of weightlessness, it is a matter of long-term incidents of changes in the blood supply to the individual areas of the body. It is due to this also that the mechanism mentioned above of variations in the oxygen exchange of the tissues appears to be likely.

The results derived, with respect to the number of measurements taken, should be considered to be only initial ones, requiring further study in subsequent manned flights. However, on the basis of the studies carried out to the present time, it may be assumed that the parameters of oxygen exchange in the tissues can be supplemented by diagnostic methods applied to evaluations of a cosmonaut's level of activity at various periods during a space flight.